Description

POLARIZATION CONVERSION METHOD FOR LIQUID CRYSTAL DISPLAYS

Technical Field

This invention relates generally to methods of converting non-polarized light into polarized light and, more, particularly, to the polarization conversion methods and are particularly useful in providing polarized input beams to projectors for liquid crystal displays.

Background Technology

Liquid Crystal (LC) light valves modulate light by changing the polarization of light passing through the birefringent LC medium. Currently, non-polarized light is converted to the polarized input light required by LC based projectors by one of a number of systems, typical examples of which are discussed later herein. In LC systems, it is generally desirable to minimize the size of the light valve in order to minimize the cost and/or size of a projector. However, reduction in light valve size results in a concomitant reduction in light output. As a result, with existing polarization conversion techniques, the components must be relatively large and expensive for efficient light collection.

The present invention is directed to overcoming one or more of the problems or disadvantages associated with the relevant technology.

Summary of the Invention

In general it would be desirable to improve polarization conversion efficiency and, at the same time, enable the use of

relatively small optical components. Accordingly, a method has been developed wherein the input beam is divided into P and S components by a polarizing beam splitter, the dimensions of which are matched to the dimensions of the input beam "waist," i.e., the minimum cross sectional size of the beam. Light passing through the optics is confined by Total Internal Reflection (TIR). The P component is confined by TIR in the polarizing beam splitter, and the S component is confined in the turning prism. The result is a polarization conversion which increases the geometrical extent by no more than a factor of two, which is the theoretical limit. TIR is achieved by providing air gaps between opposing surfaces of the optical components or by joining the surfaces with low refractive index optical cement.

Brief Description of the Drawings

Figures 1a and 1b are diagrammatic illustrations of prior art polarization conversion techniques using collimated light;

Figures 2a and 2b are diagrammatic illustrations of the limitations of prior art systems;

Figure 3 is a diagrammatic illustration of the principle of the present invention;

Figures 4a, 4b and 4c are side elevational, top plan and rear elevational views, respectively, of the optical elements employed in Figure 3; and

Figure 5 is a side elevational view of a modified version of the elements of Figure 4a.

Best Mode for Carrying Out the Invention

In the conventional polarization conversion technique illustrated in Figure 1a, a beam 10 of non-polarized light is directed into the polarizing optics 12 from left to right. The

beam is divided by 45o polarizing beam splitter 14 into P and S components. The S component beam is reflected by mirror 16 and the P component beam passes through ½ wave retarder 18 to place it in phase with the S component, the full output beam then being S polarized. The same effect is achieved using first and second lens arrays in the example of Figure 1b.

The diagrams of Figures 2a and 2b illustrate why conventional polarization conversion systems become inefficient by attempting to minimize optical component dimensions and why the geometrical extent (etendue) of the output beam increases by attempting to improve efficiency. Referring to Figure 2a, the input beam waist A-B is arbitrarily chosen to coincide with the input face 20 of prism 22. The P component passes through 45o beam splitter 24 and ½ wave retarder 26. The S component is shown being reflected by splitter 24 and mirror 26, creating a virtual image of the waist A-B at A′-B′. Since the virtual image is not coplanar with the waist, the geometrical extent of the beam increases by more than a factor of two. Figure 2b illustrates the effect of increasing the waist from A-B to C-D. The outer rays through C-D undergo extra reflections, leading to virtual source images C′ and D′, respectively. Thus, the geometrical extent is even further increased from that of the Figure 2a example.

The best mode for carrying out the present invention is through non-imaging polarization conversion with Total Internal Reflection (TIR) employed in the optics, as illustrated in Figures 4a - 4c and the modified form of Figure 5 described below.

Functional Description

The input beam aperture is defined by the dimensions of side b of polarizing beam splitter 28. Side b is coplanar with the waist of the input beam which is often elliptical, as shown in

Figure 4c, and the height b1 and with b2 of rectangular side b are chosen to correspond to the minor and major axes, respectively, of the ellipse.

The P component is confined by TIR in the polarizing beam splitter at sides a and a', whereas the S component is confined in the turning prism 30 by TIR at sides b and c', and by the sides S1 and S2 of prism 30 (Fig. 4b). The result is a polarization conversion that increases the geometrical extent by a factor of not more than two, which is the theoretical limit. TIR is achieved by providing an air gap at 32 between opposing surfaces of the beam splitter and prism 30, and at 34 between the beam splitter and ½ wave retarder 36, as shown in Figure 4a.

Alternatively, TIR may be provided by using low refractive index optical cement in layers 38 and 40 between the optical components, as shown in Figure 5. Thus, polarization conversion efficiency is improved without increasing the size of the optical components.

Other aspects and features of the present invention can be obtained from a study of the drawings, the disclosure, and the appended claims.